NEW UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. 1.53(b))

Docket No.
Ji 4-1-26
Ref. No.: L7480.0196/P196

Total pages in this submission

TO THE ASSISTANT COMMISSIONER FOR PATENTS
Box Patent Application
Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

CALL ADMISSION CONTROL WITH OVERBOOKING SUPPORT AND CELL LOSS RATIO AND CELL DELAY VARIATION GUARANTEE

and invented by:

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IF A CONTINUATION APPLICATION, check appropriate box and supply requisite information:

☐ Continuation ☐ Divisional

☐ Continuation-in-part (CIP) of prior application No.: ____________

Enclosed are:

Application Elements

1. ☐ Filing fee as calculated and transmitted as described below

2. ☒ Specification having 43 pages(s) and including the following:

   a. ☒ Descriptive title of the invention
   b. ☐ Cross references to related applications *(if applicable)*
   c. ☐ Statement regarding Federally-sponsored research/development *(if applicable)*
   d. ☐ Reference to microfiche appendix *(if applicable)*
   e. ☒ Background of the invention
   f. ☒ Brief summary of the invention
   g. ☒ Brief description of the drawings *(if drawings filed)*
   h. ☒ Detailed description
   i. ☒ Claims as classified below
   j. ☒ Abstract of the disclosure

1189737 v1; P$0901!.DOC

Application Elements (continued)

3. [X] Drawing(s) *(when necessary as prescribed by 35 U.S.C. 113)*

   [X] Formal   [ ] Informal   Number of sheets: 8

4. [X] Oath or Declaration

   a. [X] Newly executed (original or copy)   [ ] Unexecuted

   b. [ ] Copy from a prior application (37 C.F.R. 1.63(d) *(for continuation/divisional applications only)*

   c. [X] With Power of Attorney   [ ] Without Power of Attorney

5. [ ] Incorporation by reference *(usable if Box 4b is checked)*
   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. [ ] Computer program in microfiche

7. [ ] Genetic sequence submission *(if applicable, all must be included)*

   a. [ ] Paper copy

   b. [ ] Computer readable copy

   c. [ ] Statement verifying identical paper and computer readable copies

Accompanying Application

8. [X] Assignment papers *(cover sheet & document(s))*

9. [ ] 37 C.F.R. 3.73(b) statement *(when there is an assignee)*

10. [ ] English translation document *(if applicable)*

11. [X] Information Disclosure Statement/PTO-1449   [X] Copies of IDS citations

12. [ ] Preliminary Amendment

13. [X] Acknowledgment postcard

14. [ ] Certified copy of priority document(s) *(if foreign priority is claimed)*

15. [ ] Certificate of Mailing

    [ ] First Class   [ ] Express Mail (Label No.: ________________)

16. [ ] Small Entity statement(s) -- # submitted ________ *(if Small Entity status claimed)*

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Accompanying Application (continued)

17. ☐ Additional enclosures *(please identify below)*:

Fee Calculation and Transmittal

The filing fee for this utility patent application is calculated and transmitted as follows:

☒ Large Entity ☐ Small Entity

CLAIMS AS FILED

For	# Filed	# Allowed	# Extra	Rate	Fee
Total Claims	79	- 20 =	59	x $18.00	$1,062.00
Independent Claims	8	- 3 =	5	x $78.00	$390.00
Multiple Dependent Claims (check if applicable) ☐					
Other Fees (specify purpose):					
				BASIC FEE	$690.00
				TOTAL FILING FEE	$2,142.00

☐ A check in the amount of ____________ to cover the total filing fee is enclosed.

☒ The Commissioner is hereby authorized to charge and Deposit Account No. 12 - 2325 as described below. A duplicate copy of this sheet is enclosed.

☒ Charge the amount of $2,142.00 as filing fee.

☒ Credit any overpayment.

☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.

☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.31(b).

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PATENT
Docket No.: Ji 4-1-26
Ref. No.: L7480.0196/P196

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR U.S. LETTERS PATENT

Title:

CALL ADMISSION CONTROL WITH OVERBOOKING SUPPORT AND CELL LOSS RATIO AND CELL DELAY VARIATION GUARANTEE

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CALL ADMISSION CONTROL WITH OVERBOOKING SUPPORT AND CELL LOSS RATIO AND CELL DELAY VARIATION GUARANTEE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to communication systems, and more particularly to call admission control for controlling access to ATM networks or IP networks with support of differentiated services.

2. Description of the Related Art

An Asynchronous Transfer Mode (ATM) network is one method for realizing a flexible and cost-effective network for handling a wide variety of communications. In an ATM network, various types of data that have various transmission rates and traffic characteristics, are multiplexed. Therefore, the multiplexed traffic load fluctuates heavily and rapidly, especially when high speed calls are multiplexed.

Call admission control (CAC) is an important element of ATM traffic management. CAC provides access by regulating the number and types of connections that can be allowed at any given time for a given amount of resources. In an ATM multi-service network, the resource demand of each connection has to be estimated as a function of several variables, including the cell-level traffic descriptors, the required quality-of-service (QOS), the states of the network resources, and the traffic-stream class or priority. When a call request is made, the

ATM network determines whether the quality of service would be suitable in all connections, including connections which are already established when the call request is accepted, and determines propriety of the acceptance according to the available services. To make this determination, it is recommended that each terminal issuing a call request should declare parameters, such as an average rate (an average bandwidth) and a peak rate (a peak bandwidth), as source traffic characteristics, and the call admission control be performed using the declared parameters.

ATM admission control can be based on either of two approaches: a direct performance-evaluation approach or an inverse resource-requirement-estimation approach. In the direct approach, the estimated cell-level performance resulting from the admission of a new connection (or call) is calculated. In the inverse approach, an EBR ("equivalent bit rate," often called the "equivalent bandwidth" or "effective bandwidth") of the new arrival is determined by some artifice or another. The connection is accepted if the remaining unassigned capacity of the route is not less than the calculated EBR. The EBR for a connection which traverses several links may vary from link to link and would be based on the source's traffic descriptors, the cell-level performance objectives, the speed of the link under consideration, and the buffer size.

Thus, in the inverse approach, call admission criteria can be expressed as follows:

$$BW_{up\text{-}cbr} + BW_{up\text{-}rtvbr} + BW_{up\text{-}nrtvbr} \leq C_p \quad (1A)$$
$$BW_{down\text{-}cbr} + BW_{down\text{-}rtvbr} + BW_{down\text{-}nrtvbr} \leq C_p \quad (1B)$$

where $BW_{up\text{-}cbr}$, $BW_{up\text{-}rtvbr}$, and $BW_{up\text{-}nrtvbr}$ are the aggregate effective bandwidth for Constant Bit Rate (CBR), real time Variable Bit Rate (rtVBR) and non-real time Variable Bit Rate (nrtVBR) upstream traffic classes and $BW_{down\text{-}cbr}$, $BW_{down\text{-}rtvbr}$, and $BW_{down\text{-}nrtvbr}$ are the aggregate effective bandwidth for CBR, rtVBR and nrtVBR downstream traffic classes, respectively, and C_p is the port bandwidth. When a new connection request, which belongs to a particular class, comes in, it is necessary to recompute the effective bandwidth for that class and then determine if the above criteria in Equations (1A) and (1B) are met.

There are problems, however, with conventional call admission control. For example, in conventional call admission control systems, there is no perfect call admission control or effective bandwidth computation, as the systems generally make approximations of the traffic models. Accordingly, the systems do not have the capacity for maintaining the communication quality or for efficiently utilizing resources of the network when the systems are supplied with calls which have many different traffic characteristics, making precision traffic control difficult to achieve.

SUMMARY OF THE INVENTION

The present invention provides novel call admission methods for admitting connections in communications networks such as ATM networks or emerging IP networks.

According to the present invention, an innovative overbooking technique is utilized which distinguishes among the different service classes. Each service class is

assigned an overbooking factor. The call admission is determined based on the overbooking factor assigned to the class and the effective bandwidth for that service class. In addition, methods are disclosed for performing appropriate bookkeeping, i.e., updating and maintaining information concerning the state of the system.

These and other advantages and features of the invention will become apparent from the following detailed description of the invention which is provided in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 illustrates in flow chart form a call admission control method that utilizes overbooking per service class in accordance with the present invention;

FIGURES 2A and 2B illustrate in flow chart form a perfect state bookkeeping method for meeting both cell loss ratio (CLR) and cell delay variation (CDV) in accordance with the present invention;

FIGURE 3 illustrates in flow chart form a method for performing perfect state bookkeeping, in accordance with the present invention, when a call release is requested;

FIGURES 4A and 4B illustrate in flow chart form an approximate state bookkeeping method for meeting both cell loss ratio (CLR) and cell delay variation (CDV) in accordance with the present invention;

FIGURE 5 illustrates in flow chart form a method for performing approximate state bookkeeping, in accordance with the present invention, when a call release is requested;

FIGURE 6A is a block diagram illustrating an access terminal used in a network in which the methods of the present invention are performed; and

FIGURE 6B illustrates in block diagram form a system configuration that includes a daisy chain arrangement of multiple access terminals illustrated in Fig. 6A.

DETAILED DESCRIPTION

The present invention will be described as set forth in the embodiments illustrated in Figs. 1-6. Other embodiments may be utilized and structural, logical or programming changes may be made without departing from the spirit or scope of the present invention.

In accordance with the present invention, an innovative overbooking technique is utilized which distinguishes among the different service classes. Each service class is assigned an overbooking factor. The call admission is determined based on the overbooking factor assigned to the class and the effective bandwidth for that service class.

Fig. 1 illustrates in flow chart form a call admission control method that utilizes overbooking per service class in accordance with the present invention. In

step 10, an overbooking factor α_i, where i is the index to the class of service, is assigned to each class of service. The default value $\alpha_i = 1$ indicates that there is no overbooking for class i. By using different overbooking factors for the different classes, the present invention distinguishes between these classes so as to maximize the bandwidth utilization of the system without sacrificing the QoS guarantee. For example, service classes typically provided with bursty traffic can be overbooked more than service classes that are typically provided with smooth traffic. The exact value that will be assigned for each class will depend on how conservative the system is desired to be. For example, for the CBR class, in which traffic characteristics are quite predictable, the overbooking factor may be close to 1, i.e., very little overbooking. For the VBR class, a value larger than 1 may be assigned to its overbooking factor, i.e., the VBR class may be overbooked more than the CBR class.

In step 20, the aggregate effective bandwidth for class i, designated C_i, is calculated. The computation of the effective bandwidth is as follows. For the CBR class, it is known in the art that a buffer size of 150 cells is sufficient to keep cell loss ratio (CLR) below 10^{-11} for a very large number of connections (about 5000) at 95% utilization. Therefore, it is reasonable to allocate this amount of buffer for the CBR class without concern for CBR traffic cell loss. Accordingly, only the cell delay variation (CDV) needs to be checked at connection admission time. Let d be the most stringent CDV requirement among CBR traffic. Further let a be the cell transmission time corresponding to the allocated CBR bandwidth. We need to ensure the QoS of CDV is guaranteed by:

$$\Pr(q_{cbr} > d/a) < \alpha \qquad (2)$$

where α denotes the desired percentile for the CDV, and q_{cbr} is the queue length of the CBR traffic. Heterogeneous CBR traffic multiplexing can be modeled as $\Sigma_i D_i/1/K$ queue. It has been shown that the queue in $\Sigma_i D_i/1/K$ can be upper bounded by the queue of an appropriate approximating $N^*D/D/1/K$ queue where the latter queue has the same number of streams as the former but the streams are homogeneous (have the same period) with the common period D such that $N/D = p$, the same load factor as in the former queue. Given the existing N_{cbr} number of CBR connections with peak cell rate (PCR) being p_i and CDV requirement d_i for $i = 1, 2, \ldots, N_{cbr}$, it is necessary to find the appropriate bandwidth allocation factor BW_{cbr} such that the tightest CDV is met by solving the following equation, which gives the queue distribution in a homogeneous queue with N_{cbr} connections with period D:

$$\Pr(\mathrm{q}_{\mathrm{cbr}} > \alpha) = \sum_{n=\alpha+1}^{N_{cbr}} C_n^{N_{cbr}} \left(\frac{n-\alpha}{D}\right)^n \left(1 - \frac{n-\alpha}{D}\right)^{N_{cbr}-n} \frac{D - N_{cbr} + \alpha}{D - n + \alpha} < \alpha \qquad (3)$$

where x =

$$\min_{i=1}^{N_{cbr}} d_i / a, D = N_{cbr} / \frac{\sum_{i=1}^{N_{cbr}} Pi}{BW_{cbr} * ShelfPCR} \qquad (4)$$

and where a is the cell transmission time given by cell size divided by BW_{cbr} * *ShelfPCR*, where *ShelfPCR* is the feeder bandwidth of the multiplexer. Bisection or a table lookup can then be used to solve the above equation and find effective bandwidth allocation $C_i = BW_{cbr}$ for the CBR traffic class.

The rt-VBR traffic class can be characterized by three parameters, p_i, m_i, b_i, which represent peak cell rate (PCR), sustainable cell rate (SCR), burst size for the i-th connection for $i = 1, 2, \ldots, N_{rtvbr}$ where N_{rtvbr} denotes the number of established rt-VBR connections. Assuming the source is modeled by on-off periods, we can compute the average ON and OFF periods by $Ton_i = b_i/p_i$, $Toff_i = b_i/(1/m_i - 1/p_i)$. The QoS requirement for rt-VBR is the cell loss ratio (CLR, denoted L_i) and the cell delay variation (CDV, denoted by d_i), where α denotes the desired percentile for the delay performance.

For loss performance, the following must be satisfied:

$$\Pr(q_{rtvbr} > B_{rtvbr}) < L_{\min} = \min_{i=1}^{N_{rtvbr}} L_i \qquad (5)$$

where q_{rtvbr} and B_{rtvbr} denote the queue occupancy and buffer allocation for rt-VBR traffic class, respectively. For delay performance, the following condition must be checked:

$$\Pr\left(q_{rtvbr} > \min_{i=1}^{N_{rtvbr}} d_i * BW_{rtvbr} * ShelfPCR \right) < \alpha \qquad (6)$$

Essentially, the cell delay performance checking is similar to cell loss checking. Accordingly, in the following it is only necessary to concentrate on the cell loss performance guarantee, and in Equation (6) the approach can be taken where traffic sources are assumed independent with exponentially distributed on and exponentially distributed off periods. The first stage consists of computing as a function of B_{rtvbr}, L_{min}, and the traffic descriptor the following lossless effective bandwidth:

$$e_i^o = \frac{Pi}{2}\left[1 - \frac{\sigma_i}{1-\alpha_i} + \sqrt{\left(1 - \frac{\sigma_i}{1-\alpha_i}\right)^2 + 4\sigma_i \frac{\alpha_i}{1-\alpha_i}}\right] \qquad (7)$$

where $x_i = m_i/p_i$ and $\sigma_i = B_{rtvbr}/(b_i \log(1/L_{min}))$.

In the second stage, the Gaussian approximation is used to estimate the loss probability which is given in terms of the error function by:

$$\Pr(q_{rtvbr} > B_{rtvbr}) \approx erf\left(\frac{BW_{rtvbr} * ShelfPCR - M}{\sqrt{V}}\right) < L_{\min} \qquad (8)$$

where

$$M = \sum_{i=1}^{N_{rtvbr}} m_i, V = \sum_{i=1}^{N_{rtvbr}} m_i\left(e_i^o - m_i\right) \qquad (9)$$

and BW_{rtvbr} is the effective bandwidth factor required to guarantee the minimum cell loss ratio. Equation (8) can be solved for $C_t = BW_{rtvbr}$ by using a table lookup of inverse error function:

$$BW_{rtvbr} = \min\left(\sum_i e_i^o, M + Q^{-1}(L_{\min})\sqrt{V}\right) / ShelfPCR \qquad (10)$$

where Q^{1} is the Q-inverse function. The Q-function is defined as:

$$Q(\alpha) = \frac{1}{\sqrt{2\pi}\int_{\alpha}^{\infty} e^{-t^2/2}\,dt} \qquad (11)$$

For $Q(x) = \alpha$, x can be expressed in terms of the error function as:

$$x = \sqrt{2}erf^{1}(1-2\alpha) \qquad (12)$$

where erf^{1} is the inverse error function.

Once the effective bandwidth C_t per service class is computed in step 20 as described above, it can be determined if a call will be admitted. A call will be admitted if:

$$\sum_i \frac{1}{\alpha i} C_i \leq C_p \qquad (13)$$

where C_p is the total bandwidth of the port, or link, in the system through which the calls are passing. In step 30, the free bandwidth at the port is determined by:

$$\mathrm{freeBW} = C_p - \sum_i \frac{1}{\alpha_i} C_i \qquad (14)$$

When a call is requesting to be admitted to the system, in step 40, it is determined if freeBW is greater than zero, i.e., if there is available bandwidth to admit the call. If freeBW is greater than zero, then in step 50 the call is admitted. If in step 40 it is determined that freeBW is less than zero, then in step 60 the call is rejected and entry into the system is denied.

Thus, in accordance with the present invention, an overbooking technique is utilized which distinguishes among the different service classes. Each service class is assigned an overbooking factor, and admission of a call is determined based on the overbooking factor assigned to the class and the effective bandwidth for that service class.

Once it has been determined in step 50 of Fig. 1 that a call can be admitted based on the overbooking, it is necessary to perform bookkeeping on the system to ensure that the system can handle the call if it is admitted. In accordance with the present invention, two types of bookkeeping can be performed: perfect state bookkeeping, and approximate state bookkeeping, as will be further described below.

Figs. 2A and 2B illustrate in flow chart form a method for performing perfect state bookkeeping, in accordance with the present invention, when a connection setup is requested. Suppose for example there are N number of connections each of which is described by the variables (p_i, m_i, b_i), which represent the peak cell rate (PCR), sustainable cell rate (SCR) and maximum burst size (MBS) of the i-the connection which shares a buffer of B cells. These state variables are initialized to be zero in the initial phase when there is no connection. The required bandwidth must be determined to meet the following two QoS requirements:

$$\Pr(q > B) < L \qquad (15A)$$

$$\Pr(q > d^* C_{alloc}) < \alpha \qquad (15B)$$

where L is the CLR requirement, d is the CDV requirement, α is the CDV percentile, and C_{alloc} is the allocated bandwidth.

When a new connection setup request, described by p, m, and b, comes in, in step 100 the effective bandwidth to meet the CLR requirement $e0^{clr}$ is computed by

$$e0^{clr} = \frac{p}{2}\left[1 - \frac{\sigma}{1-x} + \sqrt{\left(1 - \frac{\sigma}{1-x}\right)^2 + 4\sigma\frac{x}{1-x}}\right] \qquad (16)$$

where $x_i = m_i/p_i$ and $\sigma_i = B/(b_i \log(1/L))$. In step 105, the variance of the traffic load for the CLR requirement $vclr$ is computed by

$$vclr = m * (e0^{clr} - m) \qquad (17)$$

In step 110, the required bandwidth C_{clr} to meet the CLR requirement is computed by

$$C_{clr} = \min\left(E0_{clr} + e0^{clr}, (M+m) + Q^{-1}(L)\sqrt{V_{clr} + vclr}\right) \qquad (18)$$

where M, V, and $E0_{clr}$ are the aggregate traffic load, variance of the aggregate traffic load, and sum of the lossless effective bandwidth to meet the CLR requirement, i.e.,

$$M = \sum m_i \qquad (19)$$

$$V_{clr} = \sum m_i\left(e0_i^{clr} - m_i\right) \qquad (20)$$

$$E0_{clr} = \sum e0_i^{clr} \qquad (21)$$

In step 115, C_{alloc} is set equal to the value determined for C_{clr} in step 110. In step 120, effective bandwidth for the new connection as well as all the existing connections to meet the CDV requirement $e0^{cdv}$ is computed by

$$e0_i^{cdv} = \frac{p_i}{2}\left[1 - \frac{\sigma_i}{1-x_i} + \sqrt{\left(1 - \frac{\sigma_i}{1-x_i}\right)^2 + 4\sigma_i \frac{x_i}{1-x_i}}\right] \qquad (22)$$

where $x_i = m_i/p_i$ and $\sigma_i = d^*C_{alloc}/(b_i \log(1/\alpha))$. In step 125, the variance of the aggregate traffic load V_{cdv} and the sum of the lossless effective bandwidth $E0_{cdv}$ to meet the CDV requirements are computed by

$$V_{cdv} = \sum m_i \left(e0_i^{cdv} - m_i\right) \tag{23}$$

$$E0_{cdv} = \sum e0_i^{cdv} \tag{24}$$

In step 130, the required bandwidth to meet the CDV requirements is computed by

$$C_{cdv} = \min\left(E0_{cdv}, M + Q^{-1}(\alpha)\sqrt{V_{cdv}}\right) \tag{25}$$

In step 135, the required bandwidth reqBW is determined by max (C_{clr}, C_{cdv}) and in step 140 the required bandwidth reqBW determined in step 135 is compared to the capacity of the port, or link, C_p, in the system through which the calls are passing. If the required bandwidth reqBW is greater than the capacity of the link C_p, then in step 145 the call is rejected. If the required bandwidth reqBW is not greater than the capacity of the link C_p, then in step 145 the call is accepted and the state

variables of the system are updated to include the accepted call as follows:

$$N = N + 1$$
$$M += m$$
$$V_{clr} += vclr$$
$$E0_{clr} += e0^{clr}$$

where N is the number of established connections. Specifically, the number of connections N is increased by one, the aggregate traffic load M is updated by adding the new connection's sustainable cell rate (SCR) m to the previous aggregate load, the aggregate variance of the traffic load V_{clr} is updated by adding the new connection's variance $vclr$ to the previous aggregate variance, and the sum of the lossless effective bandwidth $E0_{clr}$ is updated by adding the new connection's lossless effective bandwidth $e0^{clr}$ to the previous effective bandwidth. Thus, in accordance with the present invention, perfect state bookkeeping is performed when a new connection setup is requested to determine if the call will be admitted or denied.

Fig. 3 illustrates in flow chart form a method for performing perfect state bookkeeping, in accordance with the present invention, when a call release is requested. In step 160 the effective bandwidth to meet the CLR requirement $e0^{clr}$ is computed using Equation (16) for the connection of the call to be released. In step 165, the variance of the traffic load $vclr$ for the call to be released is computed using Equation (17). In step 170, the state variables are updated as follows:

$$N = N - 1$$
$$M -= m$$
$$Vclr -= vclr$$
$$E0_{clr} -= e0^{clr}$$

Specifically, the number of connections N is decreased by one, the aggregate traffic load M is updated by subtracting the sustainable cell rate (SCR) m of the call to be released from the previous aggregate load, the aggregate variance of the traffic load V_{clr} is updated by subtracting the variance $vclr$ of the call to be released from the previous aggregate variance, and the sum of the lossless effective bandwidth $E0_{clr}$ is updated by subtracting the lossless effective bandwidth $e0^{clr}$ of the call to be released from the previous effective bandwidth.

In step 175, the required bandwidth to meet the CLR requirement is computed by

$$C_{clr} = \min\left(E0_{clr}, M + Q^{-1}(L)\sqrt{V_{clr}}\right) \qquad (26)$$

In step 180, C_{alloc} is set equal to the value determined for C_{clr} in step 175. In step 185, effective bandwidth $e0^{cdv}$ for the connection of the call to be released as well as all the existing connections to meet the CDV requirement is computed using Equation (22). In step 190, the variance of the aggregate traffic load V_{cdv} and the sum of the lossless effective bandwidth $E0_{cdv}$ to meet the CDV requirement are computed using Equation (23) and (24), respectively. In step 195, the required bandwidth C_{cdv} to meet the CDV requirements is computed using Equation (25). In step 200, the required bandwidth reqBW is allocated, where reqBW = max (C_{clr}, C_{cdv}), and in step 205 the call is released.

Figs. 4A and 4B illustrate in flow chart form a method for approximate state bookkeeping, in accordance with the present invention, when a connection setup is requested. The approximate state bookkeeping is similar to the perfect state bookkeeping described in Figs. 2A and 2B, except that it is not required to re-compute $e0^{cdv}$ for all existing connections when a connection setup is coming.

When a new connection setup c_t request, described by p, m, and b, comes in, in step 220 the effective bandwidth to meet the CLR requirement $e0^{clr}$ is computed using Equation (16). In step 225, the variance of the traffic load $vclr$ is computed using Equation (17). In step 230, the required bandwidth C_{clr} to meet the CLR requirement is computed using Equation (18). In step 235, C_{alloc} is set equal to the value determined for C_{clr} in step 230. In step 240, effective bandwidth $e0^{cdv}$ for the new connection to meet the CDV requirement is computed using Equation (22). In step 245, the variance of the traffic load $vcdv$ is set equal to $m(e0^{cdv} - m)$ and $e0cdv$ is assigned the value of $e0_{cdv}$ computed in step 240 for each connection c_t. In step 250, the required bandwidth to meet the CDV requirements is computed by

$$C_{cdv} = \min\left(E0_{cdv} + e0^{cdv}, (M + m) + Q^{-1}(\alpha)\sqrt{V_{cdv} + vcdv}\right) \qquad (27)$$

In step 255, the required bandwidth reqBW is determined by max (C_{clr}, C_{cdv}) and in step 260 the required bandwidth reqBW determined in step 255 is compared to the capacity of the port, or link, C_p, in the system through which the calls are passing. If the required bandwidth reqBW is greater than the capacity of the link C_p,

then in step 265 the call is rejected. If the required bandwidth reqBW is not greater than the capacity of the link C_p, then in step 270 the call is accepted and the state variables of the system are updated to include the accepted call as follows:

$$\begin{aligned} N &= N + 1 \\ M &+= m \\ Vclr &+= vclr \\ E0_{clr} &+= e0^{clr} \\ V_{cdv} &+= vcdv \\ E0_{cdv} &+= e0_{cdv} \end{aligned}$$

Specifically, the number of connections N is increased by one, the aggregate traffic load M is updated by adding the new connection's sustainable cell rate (SCR) m to the previous aggregate load, the aggregate variance of the traffic load V_{clr} is updated by adding the new connection's variance $vclr$ to the previous aggregate variance, the sum of the lossless effective bandwidth $E0_{clr}$ is updated by adding the new connection's lossless effective bandwidth $e0^{clr}$ to the previous effective bandwidth, the aggregate variance of the traffic load V_{cdv} is updated by adding the new connection's variance $vcdv$ to the previous aggregate variance, and the sum of the lossless effective bandwidth $E0_{cdv}$ is updated by adding the new connection's lossless effective bandwidth $e0^{cdv}$ to the previous effective bandwidth. Thus, in accordance with the present invention, perfect state bookkeeping is performed when a new connection setup is requested to determine if the call will be admitted or denied.

Fig. 5 illustrates in flow chart form a method for performing approximate state bookkeeping, in accordance with the present invention, when a call release is requested. In step 300, the effective bandwidth to meet the CDV requirement $e0^{cdv}$

is obtained for the call to be released c_i, which is the value for $e0cdv$ computed when the call is set up. In step 305, the variance of the traffic load $vcdv$ is calculated using the value for $e0^{cdv}$ obtained in step 300. In step 310 the effective bandwidth to meet the CLR requirement $e0^{clr}$ is computed using Equation (16) for the connection of the call to be released. In step 315, the variance of the traffic load $vclr$ of the call to be released is computed using Equation (17). In step 320, the state variables are updated as follows:

$$
\begin{aligned}
N &= N - 1 \\
M- &= m \\
Vclr - &= vclr \\
E0_{clr}- &= e0^{clr} \\
V_{cdv}- &= vcdv \\
E0_{cdv}- &= e0^{cdv}
\end{aligned}
$$

Specifically, the number of connections N is decreased by one, the aggregate traffic load M is updated by subtracting the sustainable cell rate (SCR) m of the call to be released from the previous aggregate load, the aggregate variance of the traffic load V_{clr} is updated by subtracting the variance $vclr$ of the call to be released from the previous aggregate variance, the sum of the lossless effective bandwidth $E0_{clr}$ is updated by subtracting the lossless effective bandwidth $e0^{clr}$ of the call to be released from the previous effective bandwidth, the aggregate variance of the traffic load V_{cdv} is updated by subtracting the variance $vcdv$ of the call to be released from the previous aggregate variance, and the sum of the lossless effective bandwidth $E0_{cdv}$ is updated by subtracting the lossless effective bandwidth $e0^{cdv}$ of the call to be released from the previous effective bandwidth.

In step 325, the required bandwidth to meet the CLR requirement is computed using Equation (26). In step 330, the required bandwidth C_{cdv} to meet the CDV requirements is computed using Equation (25). In step 335, the required bandwidth reqBW is allocated, where reqBW = max (C_{clr}, C_{cdv}), and in step 340 the call is released.

The methods of the present invention are implemented in software and, for an ATM or IP network, are to be executed within each access terminal of the network. Fig. 6A illustrates an exemplary access terminal 400 connected to a network 420 by a feeder line 422 and a plurality of distribution lines 408 for customer connections or subscriber ports. The access terminal 400 can be located in a central office or at a remote location. The access terminal 400 includes at least one microprocessor 402, memory circuit 404, and multiplexer/demultiplexer 406. It should be appreciated that an access terminal may contain numerous microprocessors, but only one microprocessor 402 is illustrated. Moreover, the exact architecture of the access terminal 400 is not important as along as it can implement the methods of the present invention as described with respect to Figs. 1-5. As is known in the art, the micro-processor 402 controls and coordinates the operations of the access terminal including, but not limited to, the call processing and power control functions. The micro-processor 402 and multiplexer/demultiplexer 406 will implement the call admission control methods of the present invention as described with reference to Figs. 1-5.

Fig. 6B illustrates in block diagram form a configuration system that includes a daisy chain arrangement of multiple access terminals 400-1, 400-2 and 400-3 as described with respect to Fig. 6A. In this configuration each access terminal 400-1, 400-2 and 400-3, or shelf, is assigned a portion of the bandwidth, i.e., capacity, of the primary feeder 422 connected to network 420, such as for example an ATM network. While three access terminals are illustrated in Fig. 6B, the invention is not so limited and any number of access terminals may be provided. The methods according to the present invention allow each access terminal to have independent bandwidth allocation while ensuring that at provisioning time the summation of the assigned bandwidth to each shelf does not exceed the bandwidth of the primary feeder 422. Thus, each access terminal can function independently of the others in the daisy chain. For example, for a system with a feeder 422 bandwidth of C and a daisy chain having n shelves, the methods according to the present invention ensure the following is complied with:

$$C = shelf\_\mathrm{PCR}_1 + shelf\_\mathrm{PCR}_2 + shelf\_\mathrm{PCR}_3 + \ldots + shelf\_\mathrm{PCR}_n \qquad (28)$$

Reference has been made to embodiments in describing the invention. However, additions, deletions, substitutions, or other modifications which would fall within the scope of the invention defined in the claims may be implemented by those skilled in the art and familiar with the disclosure of the invention without departing from the spirit or scope of the invention. Also, although the invention is described as implemented by a programmable controller, preferably a microprocessor running a software program, it may be implemented in hardware, software, or any

combination of the two. All are deemed equivalent with respect to the operation of the invention. Additionally, while the invention has been described with respect to ATM/IP networks, the invention is not so limited and may be used with any type of communication system, including for example wireless communication systems. Accordingly, the invention is not to be considered as limited by the foregoing description, but is only limited by the scope of the appended claims.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A method for controlling call admission to a communication system comprising:

assigning a respective overbooking factor to each of a plurality of service classes;

determining an effective bandwidth for each class based in part on said respective assigned overbooking factor;

determining a value of a free bandwidth in said communication system based in part on said determined effective bandwidth for each service class; and

admitting or rejecting said call based on said determined value for said free bandwidth.

2. The method according to claim 1, wherein said step of determining a free bandwidth further comprises:

determining a maximum bandwidth at a port in the communication system; and

subtracting at least a portion of the effective bandwidth for each class from said maximum bandwidth.

3. The method according to claim 2, wherein said step of subtracting further comprises:

dividing the effective bandwidth for each class by its respective assigned overbooking factor to produce a result; and

subtracting said result from said maximum bandwidth.

4. The method according to claim 1, wherein said step of admitting or rejecting further comprises:

admitting said call if said free bandwidth is greater than zero.

5. The method according to claim 4, wherein said step of admitting or rejecting further comprises:

rejecting said call if said free bandwidth is less than zero.

6. The method according to claim 1, wherein said plurality of service classes includes a constant bit rate class.

7. The method according to claim 1, wherein said plurality of service classes includes a variable bit rate class.

8. The method according to claim 7, wherein said variable bit rate class includes a real time variable bit rate class.

9. The method according to claim 7, wherein said variable bit rate class includes a non-real time variable bit rate class.

10. The method according to claim 1, wherein said assigned overbooking factor has a default value indicating no overbooking.

11. The method according to claim 10, wherein said default value is 1.

12. The method according to claim 1, wherein said communication system is an ATM network.

13. The method according to claim 1, wherein said communication system is an IP network.

14. A method for performing bookkeeping in a communication system when a new connection setup is requested comprising:

calculating an effective bandwidth of the new connection to meet a first predetermined criteria;

calculating a variance for a traffic load of the new connection;

calculating a required bandwidth for all calls in the system to meet the first predetermined criteria based in part on said effective bandwidth and said variance of the new connection;

calculating an effective bandwidth of the new connection to meet a second predetermined criteria;

calculating a required bandwidth for all calls in the system to meet the second predetermined criteria;

calculating a required system bandwidth based on a maximum value for said required bandwidth for all calls in the system to meet the first predetermined criteria and said required bandwidth for all calls in the system to meet the second predetermined criteria;

comparing said required system bandwidth to a maximum bandwidth of said system; and

admitting or rejecting said call based on said comparison.

15. The method according to claim 14, further comprising:

updating state variables of the system if said call is admitted.

16. The method according to claim 14, wherein said step of admitting or rejecting further comprises:

admitting said call if said required system bandwidth is less than said maximum bandwidth.

17. The method according to claim 16, wherein said step of admitting or rejecting further comprises:

rejecting said call if said required system bandwidth is greater than said maximum bandwidth.

18. The method according to claim 14, wherein said first predetermined criteria is a cell loss ratio.

19. The method according to claim 18, wherein said second predetermined criteria is a cell delay variation.

20. The method according to claim 14, wherein said step of calculating an effective bandwidth of the new connection to meet a second predetermined criteria further comprises:

calculating an effective bandwidth of all calls in the system to meet the second predetermined criteria.

21. The method according to claim 20, further comprising:

updating state variables of the system if said call is admitted.

22. The method according to claim 20, wherein said step of admitting or rejecting further comprises:

admitting said call if said required system bandwidth is less than said maximum bandwidth.

23. The method according to claim 22, wherein said step of admitting or rejecting further comprises:

rejecting said call if said required system bandwidth is greater than said maximum bandwidth.

24. The method according to claim 20, wherein said first predetermined criteria is a cell loss ratio.

25. The method according to claim 24, wherein said second predetermined criteria is a cell delay variation.

26. The method according to claim 14, wherein said communication system is a wireless communication system.

27. A method for performing bookkeeping in a communication system when an existing call requests to be released from the system comprising:

calculating an effective bandwidth of the call requested to be released that satisfies a first predetermined criteria;

calculating a variance for a traffic load of the call requested to be released;

calculating a required bandwidth for all remaining calls in the system that satisfies the first predetermined criteria;

calculating an effective bandwidth of the call requesting to be released and all remaining calls in the system that satisfies a second predetermined criteria;

calculating a required bandwidth for all remaining calls in the system that satisfies the second predetermined criteria;

allocating a required system bandwidth based on a maximum value for said required bandwidth for all remaining calls in the system that satisfies the first predetermined criteria and said required bandwidth for all remaining calls in the system that satisfies the second predetermined criteria; and

releasing the call requesting to be released.

28. The method according to claim 27, wherein said step of calculating a variance further comprises:

updating state variables of the system based on said call requesting to be released.

29. The method according to claim 27, wherein said first predetermined criteria is a cell loss ratio.

30. The method according to claim 29, wherein said second predetermined criteria is a cell delay variation.

31. The method according to claim 27, wherein said communication system is an ATM network.

32. The method according to claim 27, wherein said communication system is an IP network.

33. A method for performing bookkeeping in a communication system when an existing call requests to be released from the system comprising:

determining an effective bandwidth that satisfies a first predetermined criteria for the call requesting to be released;

calculating a variance for a traffic load of the call requesting to be released for said first predetermined criteria;

calculating an effective bandwidth of the call requesting to be released that satisfies a second predetermined criteria;

calculating a variance for a traffic load of the call requesting to be released for said second predetermined criteria;

calculating a required bandwidth of all remaining calls in the system that satisfies the first predetermined criteria;

calculating an effective bandwidth of all remaining calls in the system that satisfies the second predetermined criteria;

allocating a required system bandwidth based on a maximum value for said required bandwidth for all remaining calls in the system that satisfies the first predetermined criteria and said required bandwidth for all remaining calls in the system that satisfies the second predetermined criteria; and

releasing the call requesting to be released.

34. The method according to claim 33, wherein said step of calculating a variance for a traffic load of the call requested to be released for said second predetermined criteria further comprises:

updating state variables of the system based on said call requesting to be released.

35. The method according to claim 33, wherein said first predetermined criteria is a cell loss ratio.

36. The method according to claim 35, wherein said second predetermined criteria is a cell delay variation.

37. The method according to claim 33, wherein said communication system is an ATM network.

38. The method according to claim 33, wherein said communication system is an IP network.

39. An access terminal for a communications system, comprising:

a multiplexer/demultiplexer unit; and

a programmed processor coupled to said multiplexer/demultiplexer unit, said programmed processor performing a method for controlling call admission to said communications system, said method comprising:

assigning a respective overbooking factor to each of a plurality of service classes;

determining an effective bandwidth for each class based in part on said respective assigned overbooking factor;

determining a value of a free bandwidth in said communication system based in part on said determined effective bandwidth for each service class; and

admitting or rejecting said call based on said determined value for said free bandwidth.

40. The access terminal according to claim 39, wherein said step of determining a free bandwidth further comprises:

determining a maximum bandwidth at a port in the communication system; and

subtracting at least a portion of the effective bandwidth for each class from said maximum bandwidth.

41. The access terminal according to claim 40, wherein said step of subtracting further comprises:

dividing the effective bandwidth for each class by its respective assigned overbooking factor to produce a result; and

subtracting said result from said maximum bandwidth.

42. The access terminal according to claim 39, wherein said step of admitting or rejecting further comprises:

admitting said call if said free bandwidth is greater than zero.

43. The access terminal according to claim 42, wherein said step of admitting or rejecting further comprises:

rejecting said call if said free bandwidth is less than zero.

44. The access terminal according to claim 39, wherein said plurality of service classes includes a constant bit rate class.

45. The access terminal according to claim 39, wherein said plurality of service classes includes a variable bit rate class.

46. The access terminal according to claim 45, wherein said variable bit rate class includes a real time variable bit rate class.

47. The access terminal according to claim 45, wherein said variable bit rate class includes a non-real time variable bit rate class.

48. The access terminal according to claim 39, wherein said assigned overbooking factor has a default value indicating no overbooking.

49. The access terminal according to claim 48, wherein said default value is 1.

50. The access terminal according to claim 39, wherein said communication system is an ATM network.

51. The access terminal according to claim 39, wherein said communication system is an IP network.

52. The access terminal according to claim 39, wherein said access terminal is daisy chained to at least one other access terminal, each of said access terminals performing said method for controlling call admission independently of the other.

53. An access terminal for a communication system, comprising:

a programmed processor for performing a method for bookkeeping in said communication system when a new connection setup is requested, said method comprising:

calculating an effective bandwidth of the new connection to meet a first predetermined criteria;

calculating a variance for a traffic load of the new connection;

calculating a required bandwidth for all calls in the system to meet the first predetermined criteria based in part on said effective bandwidth and said variance of the new connection;

calculating an effective bandwidth of the new connection to meet a second predetermined criteria;

calculating a required bandwidth for all calls in the system to meet the second predetermined criteria;

calculating a required system bandwidth based on a maximum value for said required bandwidth for all calls in the system to meet the first predetermined criteria and said required bandwidth for all calls in the system to meet the second predetermined criteria;

comparing said required system bandwidth to a maximum bandwidth of said system; and

admitting or rejecting said call based on said comparison.

54. The access terminal according to claim 53, wherein said method further comprises:

updating state variables of the system if said call is admitted.

55. The access terminal according to claim 53, wherein said step of admitting or rejecting further comprises:

admitting said call if said required system bandwidth is less than said maximum bandwidth.

56. The access terminal according to claim 55, wherein said step of admitting or rejecting further comprises:

rejecting said call if said required system bandwidth is greater than said maximum bandwidth.

57. The access terminal according to claim 53, wherein said first predetermined criteria is a cell loss ratio.

58. The access terminal according to claim 57, wherein said second predetermined criteria is a cell delay variation.

59. The access terminal according to claim 53, wherein said step of calculating an effective bandwidth of the new connection to meet a second predetermined criteria further comprises:

calculating an effective bandwidth of all calls in the system to meet the second predetermined criteria.

60. The access terminal according to claim 59, wherein said method further comprises:

updating state variables of the system if said call is admitted.

61. The access terminal according to claim 59, wherein said step of admitting or rejecting further comprises:

admitting said call if said required system bandwidth is less than said maximum bandwidth.

62. The access terminal according to claim 61, wherein said step of admitting or rejecting further comprises:

rejecting said call if said required system bandwidth is greater than said maximum bandwidth.

63. The access terminal according to claim 59, wherein said first predetermined criteria is a cell loss ratio.

64. The access terminal according to claim 63, wherein said second predetermined criteria is a cell delay variation.

65. The access terminal according to claim 53, wherein said communication system is an ATM network.

66. The access terminal according to claim 53, wherein said communication system is an IP network.

67. The access terminal according to claim 53, wherein said access terminal is daisy chained to at least one other access terminal, each of said access terminals performing said method for controlling call admission independently of the other.

68. A telecommunications apparatus, comprising:

a programmed processor for performing a method for bookkeeping in a communication system when an existing call requests to be released from the system, said method comprising:

calculating an effective bandwidth of the call requested to be released that satisfies a first predetermined criteria;

calculating a variance for a traffic load of the call requested to be released;

calculating a required bandwidth for all remaining calls in the system that satisfies the first predetermined criteria;

calculating an effective bandwidth of the call requesting to be released and all remaining calls in the system that satisfies a second predetermined criteria;

calculating a required bandwidth for all remaining calls in the system that satisfies the second predetermined criteria;

allocating a required system bandwidth based on a maximum value for said required bandwidth for all remaining calls in the system that satisfies the first predetermined criteria and said required bandwidth for all remaining calls in the system that satisfies the second predetermined criteria; and

releasing the call requesting to be released.

69. The apparatus to claim 68, wherein said step of calculating a variance further comprises:

updating state variables of the system based on said call requesting to be released.

70. The apparatus according to claim 68, wherein said first predetermined criteria is a cell loss ratio.

71. The apparatus according to claim 70, wherein said second predetermined criteria is a cell delay variation.

72. The apparatus according to claim 68, wherein said communication system is an ATM network.

73. The apparatus according to claim 68, wherein said communication system is an IP network.

74. A telecommunications apparatus, comprising:

a programmed processor for performing a method for bookkeeping in a communication system when an existing call requests to be released from the system, said method comprising:

determining an effective bandwidth that satisfies a first predetermined criteria for the call requesting to be released;

calculating a variance for a traffic load of the call requesting to be released for said first predetermined criteria;

calculating an effective bandwidth of the call requesting to be released that satisfies a second predetermined criteria;

calculating a variance for a traffic load of the call requesting to be released for said second predetermined criteria;

calculating a required bandwidth of all remaining calls in the system that satisfies the first predetermined criteria;

calculating an effective bandwidth of all remaining calls in the system that satisfies the second predetermined criteria;

allocating a required system bandwidth based on a maximum value for said required bandwidth for all remaining calls in the system that satisfies the first predetermined criteria and said required bandwidth for all remaining calls in the system that satisfies the second predetermined criteria; and

releasing the call requesting to be released.

75. The apparatus according to claim 74, wherein said step of calculating a variance for a traffic load of the call requested to be released for said second predetermined criteria further comprises:

updating state variables of the system based on said call requesting to be released.

76. The apparatus according to claim 74, wherein said first predetermined criteria is a cell delay variation.

77. The apparatus according to claim 76, wherein said second predetermined criteria is a cell loss ratio.

78. The apparatus according to claim 74, wherein said communication system is a wireless communication system.

79. The apparatus according to claim 74, wherein said apparatus is daisy chained to at least one other apparatus, each of said apparatuses performing said method for controlling call admission independently of the other.

ABSTRACT

Call admission methods for admitting connections into ATM/IP networks having a plurality of communication channels are disclosed. An overbooking technique is utilized which distinguishes among the different service classes. Each service class is assigned an overbooking factor. The call admission is determined based on the overbooking factor assigned to the class and the effective bandwidth for that service class. In addition, methods are disclosed for performing appropriate bookkeeping, i.e., updating and maintaining information concerning the state of the system.

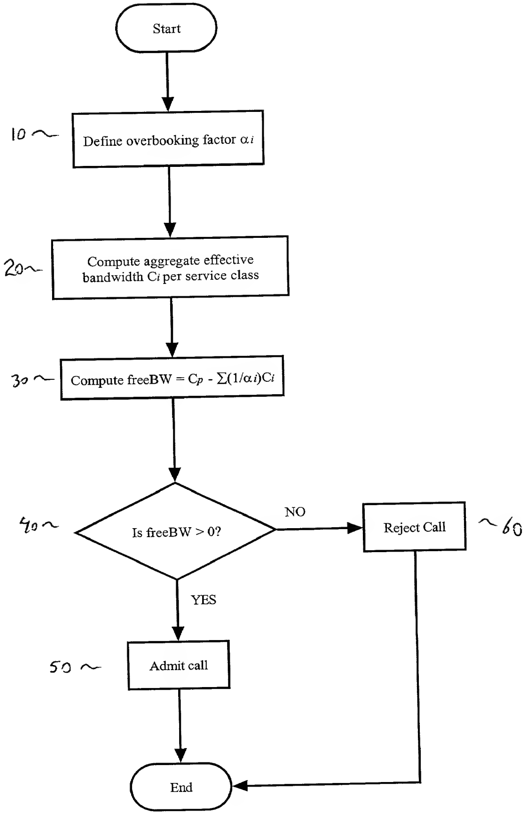

Start
10
Define overbooking factor αi
20
Compute aggregate effective bandwidth Ci per service class
30
Compute freeBW = Cp - Σ(1/αi)Ci
40
Is freeBW > 0?
NO
Reject Call
60
YES
50
Admit call
End

FIG. 1

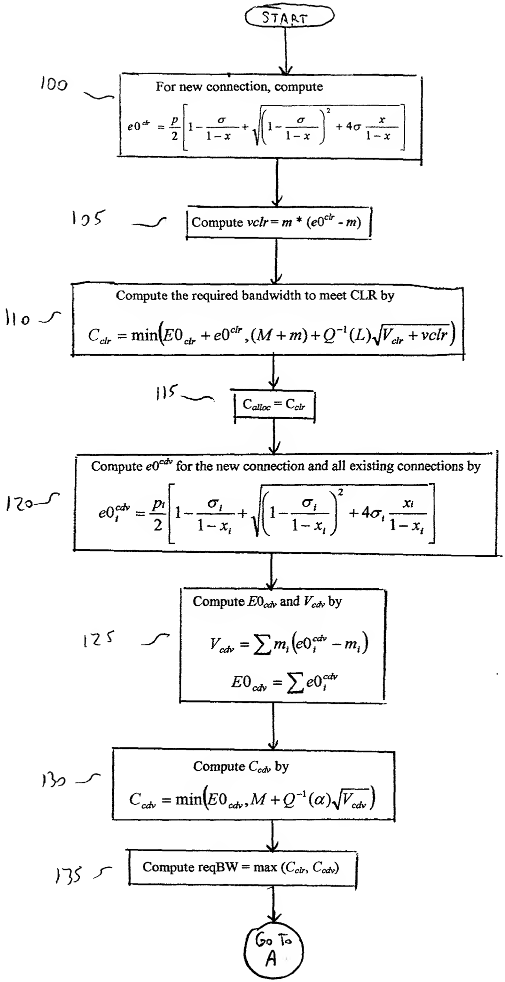

START
100
For new connection, compute
$e0^{clr} = \frac{p}{2}\left[1 - \frac{\sigma}{1-x} + \sqrt{\left(1 - \frac{\sigma}{1-x}\right)^2 + 4\sigma\frac{x}{1-x}}\right]$
105
Compute $vclr = m * (e0^{clr} - m)$
110
Compute the required bandwidth to meet CLR by
$C_{clr} = \min\left(E0_{clr} + e0^{clr}, (M+m) + Q^{-1}(L)\sqrt{V_{clr} + vclr}\right)$
115
$C_{alloc} = C_{clr}$
120
Compute $e0^{cdv}$ for the new connection and all existing connections by
$e0_i^{cdv} = \frac{p_i}{2}\left[1 - \frac{\sigma_i}{1-x_i} + \sqrt{\left(1 - \frac{\sigma_i}{1-x_i}\right)^2 + 4\sigma_i\frac{x_i}{1-x_i}}\right]$
125
Compute $E0_{cdv}$ and V_{cdv} by
$V_{cdv} = \sum m_i\left(e0_i^{cdv} - m_i\right)$
$E0_{cdv} = \sum e0_i^{cdv}$
130
Compute C_{cdv} by
$C_{cdv} = \min\left(E0_{cdv}, M + Q^{-1}(\alpha)\sqrt{V_{cdv}}\right)$
135
Compute reqBW = max (C_{clr}, C_{cdv})
Go To A

FIG 2A

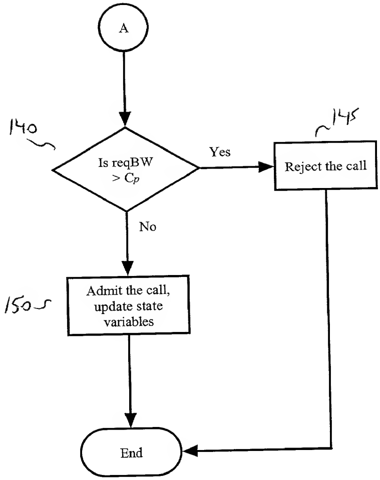

A
140
Is reqBW
> Cp
Yes
145
Reject the call
No
150
Admit the call,
update state
variables
End

Fig. 2B

START

160 For call releasing, compute

$$e0^{clr} = \frac{p}{2}\left[1-\frac{\sigma}{1-x}+\sqrt{\left(1-\frac{\sigma}{1-x}\right)^2+4\sigma\frac{x}{1-x}}\right]$$

165 Compute $vclr = m * (e0^{clr} - m)$

170 Update state variables

175 Compute the required bandwidth to meet CLR by

$$C_{clr} = \min\left(E0_{clr}, M + Q^{-1}(L)\sqrt{V_{clr}}\right)$$

180 $C_{alloc} = C_{clr}$

185 Compute $e0^{cdv}$ for call releasing and all existing connections by

$$e0_i^{cdv} = \frac{pi}{2}\left[1-\frac{\sigma_i}{1-x_i}+\sqrt{\left(1-\frac{\sigma_i}{1-x_i}\right)^2+4\sigma_i\frac{xi}{1-x_i}}\right]$$

190 Compute $E0_{cdv}$ and V_{cdv} by

$$V_{cdv} = \sum m_i\left(e0_i^{cdv} - m_i\right)$$

$$E0_{cdv} = \sum e0_i^{cdv}$$

195 Compute C_{cdv} by

$$C_{cdv} = \min\left(E0_{cdv}, M + Q^{-1}(\alpha)\sqrt{V_{cdv}}\right)$$

200 Allocate the bandwidth by reqBW = max (C_{clr}, C_{cdv})

205 Release the call

FIG 3

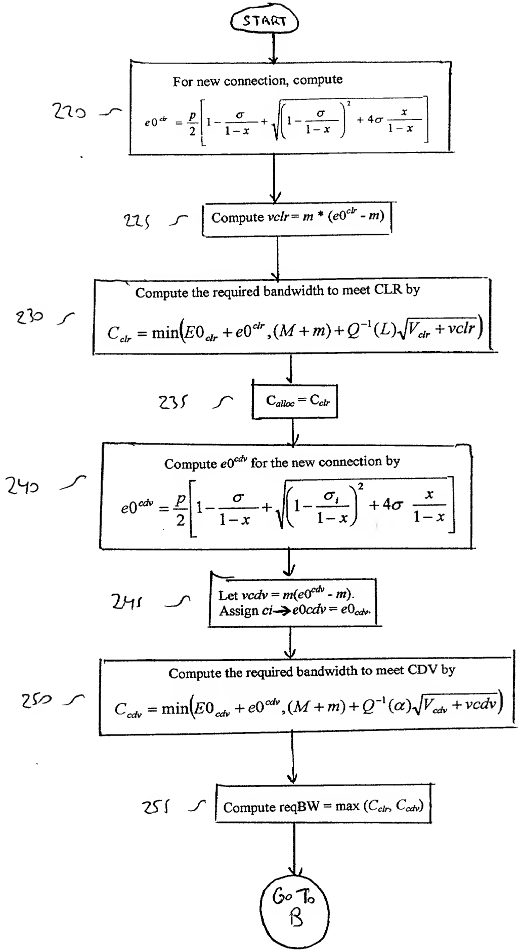

START
220
For new connection, compute
$e0^{clr} = \frac{p}{2}\left[1-\frac{\sigma}{1-x}+\sqrt{\left(1-\frac{\sigma}{1-x}\right)^2+4\sigma\frac{x}{1-x}}\right]$
225
Compute $vclr = m * (e0^{clr} - m)$
230
Compute the required bandwidth to meet CLR by
$C_{clr} = \min\left(E0_{clr} + e0^{clr}, (M+m) + Q^{-1}(L)\sqrt{V_{clr} + vclr}\right)$
235
$C_{alloc} = C_{clr}$
240
Compute $e0^{cdv}$ for the new connection by
$e0^{cdv} = \frac{p}{2}\left[1-\frac{\sigma}{1-x}+\sqrt{\left(1-\frac{\sigma_i}{1-x}\right)^2+4\sigma\frac{x}{1-x}}\right]$
245
Let $vcdv = m(e0^{cdv} - m)$.
Assign $ci \rightarrow e0cdv = e0_{cdv}$.
250
Compute the required bandwidth to meet CDV by
$C_{cdv} = \min\left(E0_{cdv} + e0^{cdv}, (M+m) + Q^{-1}(\alpha)\sqrt{V_{cdv} + vcdv}\right)$
255
Compute reqBW = max (C_{clr}, C_{cdv})
Go To B

FIG. 4A

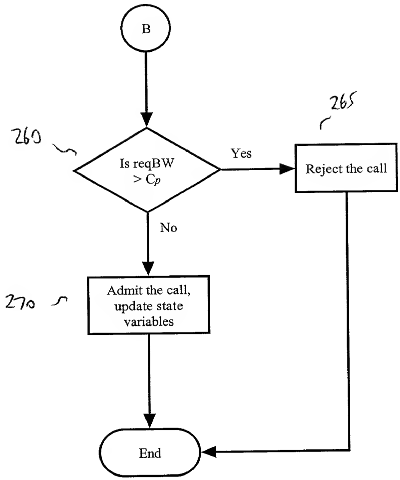

B
260
Is reqBW
> Cp
Yes
265
Reject the call
No
270
Admit the call,
update state
variables
End

Fig. 4B

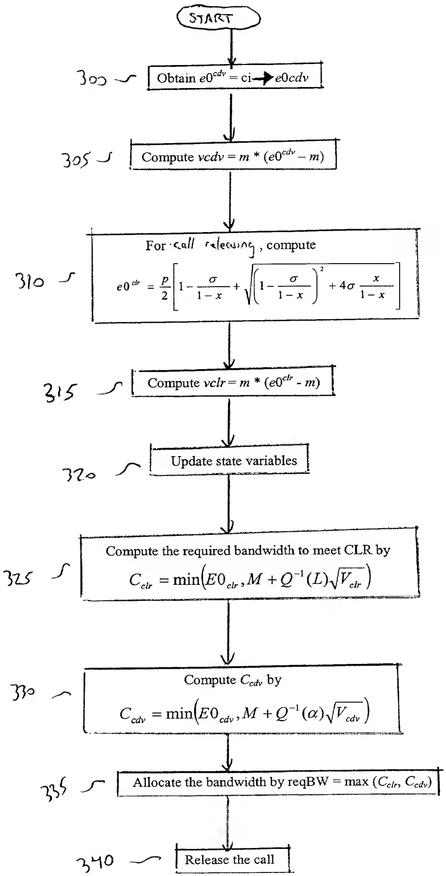
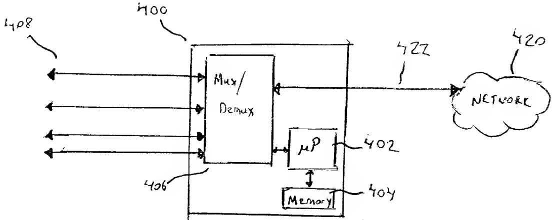
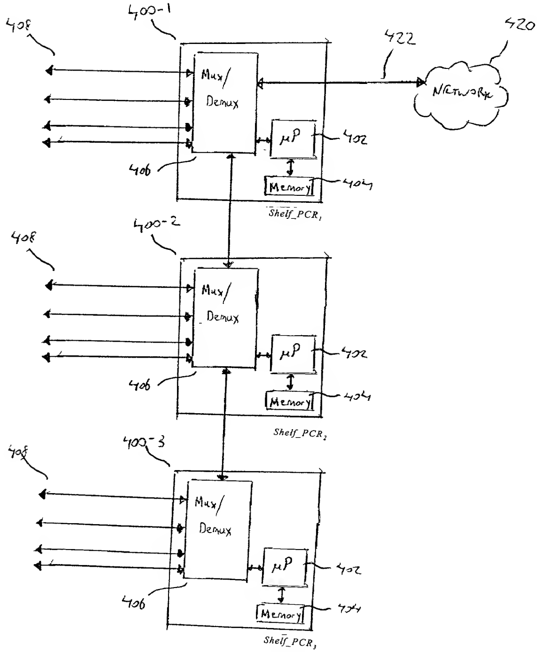

START
300
Obtain $e0^{cdv}$ = ci → $e0cdv$
305
Compute $vcdv = m * (e0^{cdv} - m)$
310
For call releasing, compute
$e0^{clr} = \frac{p}{2}\left[1 - \frac{\sigma}{1-x} + \sqrt{\left(1 - \frac{\sigma}{1-x}\right)^2 + 4\sigma\frac{x}{1-x}}\right]$
315
Compute $vclr = m * (e0^{clr} - m)$
320
Update state variables
325
Compute the required bandwidth to meet CLR by
$C_{clr} = \min\left(E0_{clr}, M + Q^{-1}(L)\sqrt{V_{clr}}\right)$
330
Compute C_{cdv} by
$C_{cdv} = \min\left(E0_{cdv}, M + Q^{-1}(\alpha)\sqrt{V_{cdv}}\right)$
335
Allocate the bandwidth by reqBW = max (C_{clr}, C_{cdv})
340
Release the call

FIG. 5



400
408
422
420
NETWORK
Mux/
Demux
μP
402
406
Memory
404

FIG. 6A



400-1
408
422
420
NETWORK
Mux/
Demux
μP
402
406
Memory
404
Shelf_PCR1
400-2
408
Mux/
Demux
μP
402
406
Memory
404
Shelf_PCR2
400-3
408
Mux/
Demux
μP
402
406
Memory
404
Shelf_PCR3

FIG. 6B

Docket No.: Ji 4-1-26
Ref. No.: L7480.0196/P196

IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

Declaration and Power of Attorney

As the below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **CALL ADMISSION CONTROL WITH OVERBOOKING SUPPORT AND CELL LOSS RATIO AND CELL DELAY VARIATION GUARANTEE** the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

None

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

None

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorney(s) with full power of substitution and revocation, to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

Thomas J. Bean	Reg. No. 44528
Lester H. Birnbaum	Reg. No. 25830
Richard J. Botos	Reg. No. 32016
Jeffery J. Brosemer	Reg. No. 36096
Kenneth M. Brown	Reg. No. 37590
Donald P. Dinella	Reg. No. 39961
Guy Eriksen	Reg. No. 41736
Martin I. Finston	Reg. No. 31613
William S. Francos	Reg. No. 38456
Barry H. Freedman	Reg. No. 26166
Julio A. Garceran	Reg. No. 37138
Jimmy Goo	Reg. No. 36528
Anthony Grillo	Reg. No. 36535
Stephen M. Gurey	Reg. No. 27336
John M. Harman	Reg. No. 38173
Matthew J. Hodulik	Reg. No. 36164
Michael B. Johannesen	Reg. No. 35557
Mark A. Kurisko	Reg. No. 38944
Irena Lager	Reg. No. 39260
Christopher N. Malvone	Reg. No. 34866
Scott W. McLellan	Reg. No. 30776
Martin G. Meder	Reg. No. 34674
John C. Moran	Reg. No. 30782
Michael A. Morra	Reg. No. 28975
Gregory J. Murgia	Reg. No. 41209
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Joseph J. Opalach	Reg. No. 36229
Neil R. Ormos	Reg. No. 35309
Eugen E. Pacher	Reg. No. 29964
Jack R. Penrod	Reg. No. 31864
Gregory C. Ranieri	Reg. No. 29695
Scott J. Rittman	Reg. No. 39010
Ferdinand M. Romano	Reg. No. 32752
Eugene J. Rosenthal	Reg. No. 36658
Bruce S. Schneider	Reg. No. 27949
Ronald D. Slusky	Reg. No. 26585
David L. Smith	Reg. No. 30592
Ozer M. N. Teitelbaum	Reg. No. 36698
John P. Veschi	Reg. No. 39058
David Volejnicek	Reg. No. 29355

Charles L. Warren	Reg. No. 27407
Jeffrey M. Weinick	Reg. No. 36304
Eli Weiss	Reg. No. 17765

I hereby appoint the attorney(s) on ATTACHMENT A as associate attorney(s) in the aforementioned application, with full power solely to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected with the prosecution of said application. No other powers are granted to such associate attorney(s) and such associate attorney(s) are specifically denied any power of substitution or revocation.

Full name of first inventor: Hongbin Ji

Inventor's signature____________________Date 08/17/2000

Residence: San Jose, Santa Clara, California

Citizenship: China

Post Office Address: 4307 Renaissance Drive #323
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Full name of second inventor: Eraj D. Kaluarachchi

Inventor's signature____________________Date__________

Residence: South Orange, Essex, New Jersey

Citizenship: Sri Lanka

Post Office Address: 17 Fairview Avenue, Apt. 2A
South Orange, NJ 07079

****

Full name of third inventor: On-Ching Yue

Inventor's signature____Date___________

Residence: Middletown, Monmouth, New Jersey

Citizenship: United States

Post Office Address: 57 Blevins Avenue
Middletown, NJ 07748

****

ATTACHMENT A

Attorney Name(s):	Gary M. Hoffman	Reg. No.:	26, 411
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	Donald A. Gregory		28,954
	James W. Brady, Jr.		32,115
	Jon D. Grossman		32,699
	Mark J. Thronson		33,082
	Donald L. Bowman		P46,432
	Christopher Chow		P46,493
	Laurence D. Fisher		37,131
	Jeremy Cubert		40399
	Brian A. Lemm		43,748
	Gianni Minutoli		41,198
	Edwin Oh		45,319
	Eric Oliver		35,307
	William E. Powell, III		39,803
	Mark Strickland		45,138
	Salvatore P. Tamburo		45,153

Telephone calls should be made to **Thomas J. D'Amico** at:

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All written communications are to be addressed to:

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Washington, D.C. 20037-1526

IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

Declaration and Power of Attorney

As the below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **CALL ADMISSION CONTROL WITH OVERBOOKING SUPPORT AND CELL LOSS RATIO AND CELL DELAY VARIATION GUARANTEE** the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

None

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

None

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Full name of second inventor: Eraj D. Kaluarachchi

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Full name of third inventor: On-Ching Yue

Inventor's signature On-Ching Yue Date 8/17/2000

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